

Why there is no crisis of the “spin crisis”

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Abstract

In a recent eprint [1] it is argued that the experimental determinations of the spin-dependent structure function g_1 have been done incorrectly and that a reanalysis of those data suggests that the original motivation to argue for a “spin crisis”, namely the small contribution of quark spins to the nucleon spin, is invalid. In a subsequent note [2] the theoretical understanding, as it has evolved from almost 30 years of theoretical and experimental scrutiny, has been shortly summarised. In this short note, arguments are presented that the line of reasoning in Ref. [1] does not apply, at least not for the COMPASS data.

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A restitution of the strongly violated Ellis–Jaffe sum rule due to the consideration of diffractive events has been put forward in a recent eprint [1]. The main argument is the claim that in the Deeply Inelastic Scattering (DIS) cross-section a fraction f of the events is non-perturbative, i.e. diffractive, which shows no spin asymmetry, and that the fraction f is large, of order 0.3–0.4. Consequently the analysing power is reduced, and one has to rescale the results for the polarised cross-section asymmetries by multiplying them by a factor $1/(1-f)$. Rescaling by the same factor is then required also for the first moments of the spin-dependent structure functions g_1 of the proton and the neutron, defined as

$$\Gamma_1^{p,n} = \int_0^1 g_1^{p,n}(x, Q^2) dx.$$

As shown in Fig. 2 of Ref. [1], when f lies between 0.3–0.4, both the HERMES and the COMPASS data should be rescaled by factors of 1.4–1.6, which would bring the singlet axial coupling a_0 (and consequently $\Delta\Sigma$, the contribution of the quark spins to the spin of the nucleon) to about 0.6, the value originally expected from the Ellis–Jaffe sum rule. This suggestion is motivated in the eprint [1] by referring to results from the H1 [3] and the ZEUS [4] experiments at HERA, which measured the ratio between the photoproduction cross-section for diffractive events and the total photoproduction cross-section. This ratio is measured to be 0.30–0.40. Their assumption is that the fraction f has to be the same in DIS, where analyses typically require the photon virtuality Q^2 to be larger than 1 GeV².

We have two comments to these considerations:

The first comment regards the amount of diffractive events in the COMPASS DIS data. Here only interactions of the resolved photon have to be considered, since hard diffraction events arise from point-like virtual photon interactions with partons from the intrinsic proton structure. The contribution of diffractive events to the COMPASS inclusive and semi-inclusive DIS (SIDIS) event samples has been studied e.g. in the context of the analysis of hadron multiplicities [10]. For the SIDIS events at least one hadron is detected in addition to the scattered lepton. The main motivations of this analysis are the extraction of the hadron multiplicities, p_T distributions and azimuthal modulations of the unpolarized cross-section normalised to the inclusive cross-section. Rather than relying on particular assumptions and on measurements done at $Q^2 = 0$, the diffractive production of vector mesons (ρ^0 , ω , ϕ , ...), was estimated for the actual COMPASS kinematics. The evaluation is based on two MC simulations, one using the LEPTO [5] event generator simulating SIDIS free of diffractive contributions, and the other one using the HEPGEN [6] generator simulating diffractive ρ^0 and ϕ production, normalised to the GPD model of Ref. [7]. Further channels, which are characterised by smaller cross-sections and more particles in the final state, are not taken into account. Besides events with the nucleon staying intact, also events with diffractive dissociation of the target nucleon are simulated. The simulation

of these events includes nuclear effects, i.e. coherent production and nuclear absorption as described in Refs. [8, 9]. Taking into account all these effects, the f values COMPASS obtains for the inclusive event sample range from 0.04 at low x and Q^2 to 0.003 at high x and Q^2 [10], a result which is in line with what is known in the literature on the amount of diffraction in DIS [11]. Consequently the effective dilution of the virtual photon polarisation in the COMPASS measurements is 10–100 times smaller than what has been assumed in Ref. [1] and well inside the systematic uncertainties.

The second comment regards the Bjorken sum rule. If the arguments in Ref. [1] were correct and indeed the first moments Γ_1^p and Γ_1^n had to be rescaled by a factor $1/(1-f) \simeq 1.5$, the Bjorken sum rule as measured from the COMPASS data alone would be violated by almost 4 standard deviations. The Bjorken sum rule was formulated already in 1956 using current algebra, and reformulated in QCD. No discrepancy with the available data on g_1^p , g_1^n and g_1^d has ever been reported (apart from an early measurement corrected later). If the rescaling suggested in Ref. [1] would be applied, a major problem would open up for QCD.

This might be the reason, why the authors of Ref. [1] claim an under-exhaustion of the fundamental Bjorken sum rule despite its verification to the 9% level by COMPASS [12]. In their eprint, they assert that in Ref. [12] the Bjorken sum is derived from a fit to the scaled world data. This is incorrect, the COMPASS result is obtained directly from the measured COMPASS g_1^{NS} non-singlet data points in the region $0.0025 < x < 0.7$ corresponding to 93.8% of the full first moment. The extrapolations to $x = 0$ and $x = 1$ amount to 3.6% and 2.6%, respectively. For these small extrapolations a fit to the COMPASS non-singlet data is used. Therefore, there is no way to turn the experimental confirmation of the Bjorken sum rule into an under-exhaustion.

In the same way the Ellis–Jaffe sums are determined [12] at $Q^2 = 3 \text{ GeV}^2$. We obtain for the proton $\Gamma_1^p = 0.139 \pm 0.010$ and for the neutron $\Gamma_1^n = -0.041 \pm 0.013$. The theoretical values are 0.172 ± 0.003 and -0.017 ± 0.003 , respectively. It remains unclear why in Ref. [1] it is stated that “... however with the realization of the idea presented in this paper the Bjorken sum as well as the Ellis–Jaffe–sum rule are in accord with the data naturally”, whereas “this realisation” leads to a clear violation of the Bjorken sum rule.

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